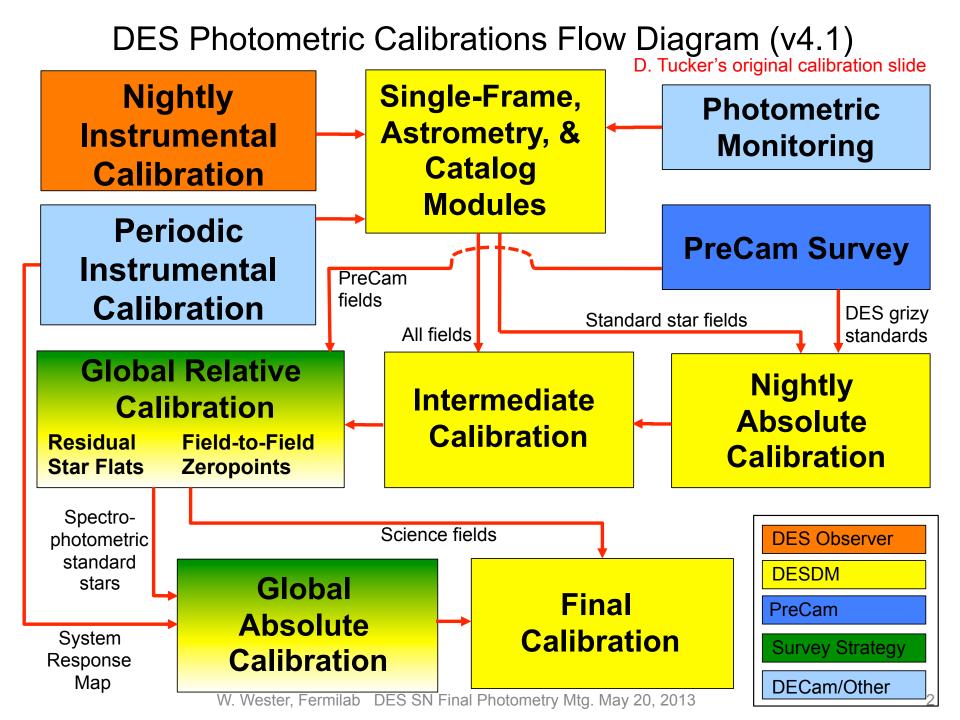


DES Calibration Overview

Photometric Goals and Requirements

- SV and 1st Year:
 - All-sky internal: 3% rms
 - Absolute Color: 3% (g-r, r-i, i-z); 4% (z-Y)
 - Absolute Flux: 3% in i-band (relative to BD+17 4708)
- 2nd Year:
 - All-sky internal: 2% rms
 - Absolute Color: 2% (g-r, r-i, i-z); 3% (z-Y)
 - Absolute Flux: 2% in i-band (relative to BD+17 4708)
- Full Survey: (from Science Requirements DocDB 20)
 - All-sky internal: 2% rms (Goal of 1%)
 - Absolute Color: 0.5% (g-r, r-i, i-z); 1% (z-Y)
 - Absolute Flux: 0.5% in i-band (relative to BD+17 4708)



DES Photometric Calibrations Flow Diagram (v4.1) D. Tucker's original calibration slide Single-Frame, Astrometry, & Nightly Instrumental Calibration **Photometric Monitoring** Catalog Modules Input: Input (every 5 minutes or less): Raw bias frames Master bias frame (nightly) 10-micron All-Sky Camera (RASICAM) Input: (each frame) Raw dark frames Master dark frames (nightly) Instrumental calibration Raw dome flats Master dome flats (nightly) Output (each target exposure): Raw science & standard star frames Photometricity flags Photometricity flag(s) (good/bad/marginal) Periodic Instrumental Calibration Catalog of RA, DEC positions and instrumental Output: Input: **PreCam Survey** magnitudes Optical model Scattered light map (once) Short/long exposures Shutter timing map (annually) Linearity exposures Linearity curves Observations with PreCam camera on Curtis-Schmidt (annually) "Victim" exposures Cross-talk coefficients (annually) System Response exposures System Response Map (monthly) Output: DES grizy standard stars DES-overlapping fields DES grizy DES-overlapping fields Standard star fields All fields standards **Global Relative Calibration** Nightly Absolute Calibration **Intermediate Calibration** Residual Star Flats Field-to-Field Zeropoints Standard star catalogs (Stripe 82, South. Stds., PreCam) Zeropoints and first order extinctions from nightly Standard star instr. mags absolute calibration Photometricity flags Instr. mags for science and standard star fields Grid test intermed. mags Intermed, mags for matched stars Stripe 82 intermed, mags (all fields from multiple tilings) Output: Photometricity flags PreCam Survey Data Photometric zeropoints and first-order extinctions to place Intermediate calibrated mags for science and standard instr. mags onto the AB mag scale (one zeropoint and one star fields Output: extinction per filter) Improved flat fields Field-to-field zeropoint offsets Nightly Star Flats (→ improved flat fields) Self-consistent relative calibration Science fields **DES Observer** Spectrophotometric Global Absolute Calibration Final Calibration standard stars DESDM White Dwarf Spectrophotometry Zeropoints from global absolute calibration Post-Global-Relative-Calibration mags of WDs Post-Global-Relative-Calibration mags for science fields **PreCam** System Response Map Survey Strategy Calibrated AB magnitudes for science fields Final overall zeropoints to place relative photometry onto the AB mag scale (one zeropoint per filter) System Response Map DECam/Other W. Wester, Fermilab DES SN Final Photometry Mtg. May 20, 2013



DARK ENERGY **SURVEY**

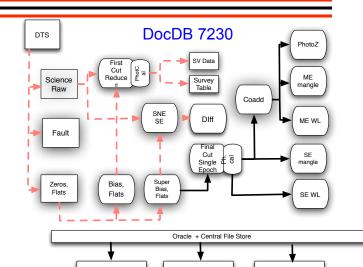
- 1. Instrumental Calibration (Nightly & Periodic): Create biases, dome flats, linearity curves, cross-talk coefficients, system response maps.
- 2. Photometric Monitoring: Monitor sky conditions with 10µm All-Sky Cloud Camera and the GPS and atmCam atmospheric transmission monitors.
- 3. PreCam Survey: Create a network of calibrated DES grizy standard stars for use in nightly calibrations and in DES Global Relative Calibrations.
- 4. Nightly and Intermediate Calibrations: Observe standard star fields with DECam during evening and morning twilight and at least once in the middle of the night; fit photometric equation; apply the results to the data.
- 5. Global Relative Calibrations: Use the extensive overlaps between exposures over multiple tilings to tie together the DES photometry onto an internally consistent system across the entire DES footprint.
- 6. Global Absolute Calibrations: Use DECam observations of spectrophotometric standards in combination with measurements of the full DECam system response map to tie the DES photometry onto an AB magnitude system. W. Wester, Fermilab DES SN Final Photometry Mtg. May 20, 2013



From the data management side

DARK ENERGY SURVEY

For the main survey, modules are added to the appropriate pipelines to implement calibration algorithms. These algorithms impact either the reduced etc. images or contents of the DESDM database (EXPOSURE, IMAGE, "OBJECTS", and PSMFIT tables)



Analysis Facilites

User's computers

Science Portal

Operational Pipelines:

https://cosmology.illinois.edu/confluence/display/Operations/Operational+Pipelines

- PreCal: process nightly calibration exposures to create calibration files for detrending
- SuperCal: combine calibration exposures across several nights to create high S/N calibration files for detrending
- FirstCut: fill out the survey table, i.e., minimal processing to determine if a raw exposure is "good enough" to be included in the survey or if it needs to be re-imaged
- · SNeSE: basic image reduction of supernova exposures in preparation for supernova difference imaging
- . FinalCut: single epoch reduction of images for cataloging and in preparation for coaddition
- . Photcal: apply the PSM solution to objects cataloged in single epoch processing
- Coadd: multi-epoch processing of images, including coaddition and object cataloging
- PhotoZ: calculate photometric redshifts

SNeSE

| OITCOL | | | | | | |
|----------------|--|--|--|--|--|--|
| Block | Module Name (click to see current configuration) | Operation | Science Codes (click for documentation) | Data In | Data Out | DB Tables |
| crosstalk | crosstalk | Apply crosstalk correction, overscan, & satmask | crosstalk.pl -> DECam_crosstalk | src (obstype = object), xtalk file | raw_obj | |
| imcorrect | imcorrect | Apply bias correction, flat correction | imcorrect | raw_obj, biascor, flatcor, bpm, photflatcor, pupil | | |
| astrorefine | catalog_exposure | Calculate astrometric solution | runSExtractor.c -> SExtractor, fwhm.c create_fullscamp.pl -> fitscombine.c | | | |
| astrorefine | scamp | Ingest astrometric solution (VO Table) | runSCAMP.pl -> SCAMP | | | |
| ingest_scampqa | ingest_scampqa | Ingest astrometric solution (VO Table) | ingestSCAMPqa.pl | scamp.xml | | |
| create_catalog | create_catalog | Create basic source catalog | runSExtractor.c> SExtractor | reduced images, sex.config, sex.conv, sex.nnw, sex.param_nopsfex | reduced image catalogs (*_cat.fits) | selects from LOCATION |
| merge_table | merge_table | Merge temporary catalog table with objects table | merge_objects | none | none | selects from tmp table, inserts in OBJECTS_CURRENT |
| compress files | compress files | Compress files created during processing | compress files | raw ohi images reduced images | compressed raw ohi & reduced images (* fz) | selects from LOCATION |



SURVEY

Nightly/Intermediate Calibrations: The Photometric Equation

 The Photometric Equation is a simple model that fits the observed magnitudes of a set of standard stars to their "true" magnitudes via a simple model; e.g.:

$$m_{inst} - m_{std} = a_n + kX \tag{1}$$

- m_{inst} is the instrumental magnitude, $m_{inst} = -2.5log(counts/sec)$ (input)
- m_{std} is the standard ("true") magnitude of the standard star (input)
- a_n is the photometric zeropoint for CCD n (n = 1-62) (output)
- k is the first-order extinction (input/output)
- X is the airmass (input)
- A refinement: add an instrumental color term for each CCD to account for small differences between the standard star system and the natural system of that CCD:

$$m_{inst} - m_{std} = a_n + b_n x (stdColor - stdColor_0) + kX$$
 (2)

- b_n is the instrumental color term coefficient for CCD n (n = 1-62) (input/output)
- stdColor is a color index, e.g., (g-r) (input)
- stdColor₀ is a constant (a fixed reference value for that passband) (input)
- DES calibrations will be in the DECam natural system, but there may be variations from CCD to CCD within the DECam focal plane or over time.
 D. Tucker



Stellar magnitudes

DARK ENERGY SURVEY

PSMFIT table has the a_n , k, and b_n coefficients for photometric nights where the PSM solution is derived from standard star observations taken typically at morning and evening twilight and also around 1AM.

- Each of the (u), g, r, I, z, Y filters
- typically SDSS stripe 82 star field
- low, medium, and high airmass

Note: some adjustments required, as SDSS standards are typically used (UKIDSS for Y), to put the magnitudes on the DES standard and on AB scale. Example:

```
. g_des = mag_psf - zeropoint + 2.5*log10(exptime) - a_ccd - b_ccd*(-0.114 - 0.530) - k*X + 0.021
```

where zeropoint is (almost?) always 25.000,

0.530 is the reference g-r color ("color0") used by PSM,

-0.114 is the g-r color where g_des=g_sdss_ab, and

+0.021 is the g-band AB offset for the SDSS Stripe82 standards currently used by DESDM

Comments welcome for a future more detailed presentation